Using Trendmaster® 2000 to Minimize Pump Repairs
Proactive Maintenance – A Successful History

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The Refinaria Presidente Bernardes de Cubatão (RPBC) in Brazil is one of ten oil refineries owned and operated by Petrobras – Brazil's state-owned oil company. Currently, this oil refinery processes 180,000 barrels per day, which accounts for fully one-tenth of all oil refining in Brazil.

In the mid-1990s, RPBC faced the challenge of aggressively lowering its maintenance costs. Had we attempted to meet this challenge by simply lowering our expenditures while using the same maintenance methodologies, we would not have succeeded. Instead, we completely re-evaluated how we were conducting maintenance and assessed the market for tools that would help us with newer proactive methods instead of older time-based maintenance or run-to-failure practices.

After careful research, among other technologies we wanted to implement, we decided to make operational decisions using better information about our equipment condition. After going through a bidding process – as required by company regulations – Bently Nevada machinery information systems were selected.

> *"The TM2000 system has already paid for itself, considering reduction in maintenance repair costs alone."*

Bently Nevada online monitoring systems have monitored both critical and essential machines at RPBC since 1996, and these systems are being expanded. Our critical machines (known as "big" machines) have Bently Nevada protection systems installed, and also include Data Manager® 2000 (DM2000) software for capturing and displaying mechanical condition information. A Trendmaster® 2000 (TM2000) system monitors the essential machinery (known as "small" machines). Both the DM2000 and TM2000 systems are connected via digital communications links to our Distributed Control System (DCS) as a means of providing machinery information to operators. This integration has a been a key part of the program's success.

Head pressure vs. flow for pump characteristics and system requirements, showing relative locations of the Best Efficiency Point (BEP) and cavitation.

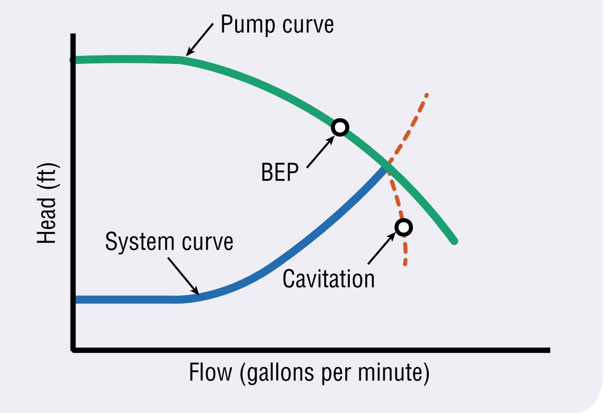

Figure 1.

This case history explains how the TM2000 system drastically reduced the number of failures in three slurry reflux pumps that were located in the Fluidic Catalytic Cracker (FCC) unit. The 134 kW (180 hp) pumps are steam turbine-driven and operate in parallel. The three pumps were designed to work with two of them running and one as a standby. With the increase in production at the refinery, all three may now be in use at the same time. Production might be greatly affected when one of them is not available.

The design characteristics of pumps make them very sensitive to the ideal operational point, which is sometimes called the Best Efficiency Point (BEP) (Figure 1). However, most pumps are operated outside this point because of increases or decreases in flow. When operated outside this point, vibration levels will increase significantly, causing stress to the pump. For example, if the system head pressure is insufficient at a given flow, some of the fluid may vaporize at the pump inlet, resulting in violent collapsing of bubbles. This phenomenon, known as cavitation, can be accompanied by dramatic increases in vibration. (Editor's Note: Please refer to the article *Detecting Cavitation in Centrifugal Pumps*, ORBIT, Vol. 21 No. 2, 2000, pp. 26-30, for more information on detecting cavitation.)

Originally, the only instrumentation feedback available to the operators was the flow level in the header and the fluid level in the cracking tower. This was insufficient to determine the control of flow to the individual pumps. When flow from one of the pumps moved outside the allowable operating region, it would vibrate in such a way that its life span drastically decreased. The refinery was experiencing broken shafts, impeller damage, excessive sealing leakage, and heavily damaged bearings approximately every two months.

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> *"After the unequal flow distribution was identified (using TM2000) as the main cause of the failures, operators started to reduce overall vibration by varying pump speed via the turbines, resulting in a more evenly distributed, steady flow to each pump."*

Figure 2 shows the trend plot for the vibration of each pump, using Bently's TM2000 system. It illustrates pump vibration while bringing pumps online and offline. For example, at approximately 11:20 a.m., pump B was taken offline due to high vibration; pump A was taken out of standby and

Vibration levels on the pumps during operator intervention

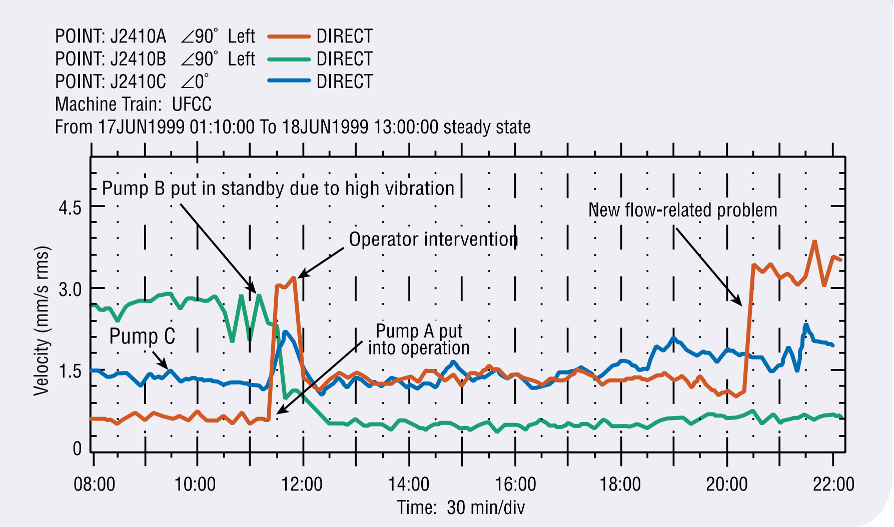

Figure 2.

Half spectrum showing predominance of 3X vibration (4080 cpm) during alarm

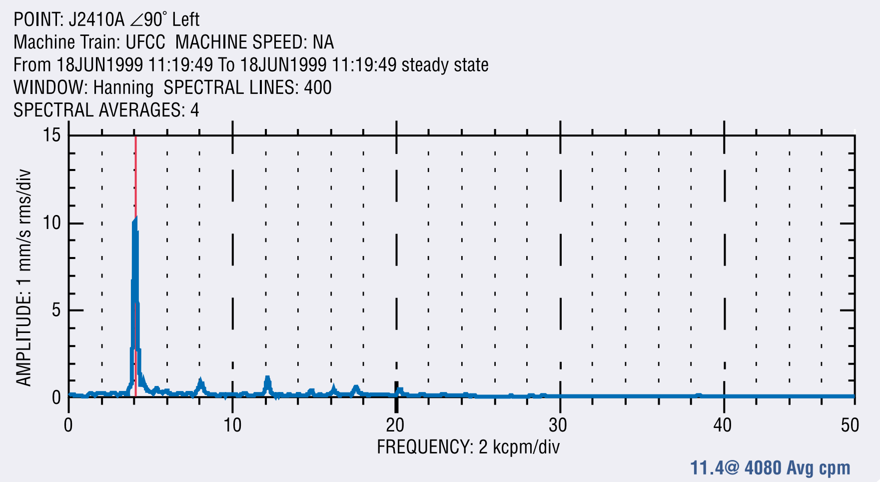

Figure 3.

put into operation, and its flow was quickly adjusted to a level near that of operating Pump C. It should be noted that when the pump is in standby, it simply re-circulates product at low speed (around 1000 rpm) and shows a minimal vibration level.

Before TM2000 was installed, casing vibration amplitude levels on the pumps were collected manually every 15 days. After TM2000 was installed in 1996 and data was collected from each pump approximately every 10 minutes, the Maintenance group could view online pump vibration data during alarm events from their desktop computers.

Consequently, they discovered that most of the vibration occurred at the vane (blade) passing frequency (3X) (Figure 3), where the pump rotational speed was in the range of 1100 rpm to 1440 rpm. Maintenance concluded that the problem was caused by flow outside of the allowable region. They realized that load was never equally distributed between the two pumps that were in use at the same time.

After the unequal flow distribution was identified (using TM2000) as the main cause of the failures, operators started to reduce overall vibration by varying pump speed via the turbines, resulting in a more evenly distributed, steady flow to each pump, thereby avoiding cavitation and excessive vibration.

During the night and weekends, the Maintenance group was not always available to monitor the pumps (using TM2000) or to advise operators when there was a significant change in the flow. To improve the operating procedure, Petrobras and Bently Nevada engineers integrated TM2000 data to the plant Distributed Control System (DCS) via TM2000 DDE (dynamic data exchange) and PI DDE interfaces.

Operators now have pump vibration levels on their screens, and control of flow has become a formal operational procedure in the plant based on the TM2000 online data.

The control of the operational flow, along with changes to the mechanical seal used on the pumps, resulted in significant savings from both pump downtime and replacement costs. Table 1, based on data from the maintenance system log, shows how often a pump was taken out of operation since 1995. The number of failures has been steadily decreasing since the installation of the Trendmaster® 2000 data acquisition system. In fact, there have been no pump failures since April 1998.

Return on Investment

The TM2000 system has already paid for itself, considering reduction in maintenance repair costs alone. The system was monitoring 213 points in the plant, with a scanning resolution of approximately every 10 minutes. The success achieved at the refinery using TM2000 has justified the addition of another 111 points, which were installed in June 2000.

The return on investment can be observed through the numbers in Table 2. These reflect only those gains

Number of maintenance interventions per pump

Pump	1995	1996	1997	1998	1999	2000*
A	4	2	2	0	0	0
B	3	2	1	2	0	0
C	3	2	1	1	0	0
Total	**10**	**6**	**4**	**3**	**0**	**0**

Installation of Trendmaster® 2000

Integrated with DCS

* to date

Table 1.

attributable to our Bently Nevada machinery management systems – when combined with the gains made through other maintenance technologies and innovations, the numbers are even more impressive. The period evaluated was December 1997 through December 1998.

The numbers in Table 2 are very encouraging. However, the intangible benefits are probably equally important. For example, maintenance used to be seen as an accessory function of production – a necessary evil. As the online maintenance system started to produce results, the maintenance team started to be consulted more and more by operators about the machinery health, and fine-tuning of operational procedures to foster better equipment health has been adopted. This is bringing the two functions inside the plant together with the single objective of producing more, for longer periods without interruption.

The paradigm shift allowing us to achieve such results was mainly due to management support and the commitment of our people to implement new methods for both operating and maintaining the plant. However, the right tools were also necessary, and our Bently Nevada online machinery management systems have been very instrumental in achieving excellent results. Another important benefit was the improvement in the quality of life of our maintenance staff. We are now working less overtime, less standby time, and less unscheduled night calls, leaving more time for proactive work and training.

In closing, perhaps the best testimony regarding the value that the machinery management system is providing is this: the further expansion of the Bently Nevada system has been *internally* requested – by Operations!

Measurement	Improvement
Mean Time To Repair (MTTR)	Reduced by 23%
Mean Time Between Failure (MTBF)	Increased by 10%
Number of machines under maintenance	Reduced by 12%
Standard Labor Costs	Reduced by 40%
Overtime Labor Costs	Reduced by 33%
Overall Maintenance Costs	Reduced by 22%

Table 2.